Q_α-Energy of Isotopes of Superheavy Nucleus: Z = 119

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Introduction

The exploration of the extent of superheavy nuclei and the center of stability of in this mass region has been a topic of interest since late sixties and the stability of nuclei in this mass region was predicted to be due to shell effects [1]. The whole story of synthesis and the studies of decay properties of unstable superheavy nuclei is largely dependent on the internal structure of the nuclei, which in turn is based on the fundamental knowledge of nuclear potentials. The fundamental question is to what extent the nuclei of superheavy elements can be synthesized and how their properties differ from the known nuclei. The nuclei at superheavy mass region must respond differently, because, as we move in the domain of heavier nuclei the Coulomb forces increase with the increase in number of protons (i.e. increase in Z number).

The 'Island of stability' in this mass region has been predicted theoretically around double shell closure at Z = 114, 120 and/or 126, at neutron number N = 184 [2]. Now, the existence of island of stability has been confirmed experimentally [3] during previous decade at Flerov Laboratory of Nuclear Reaction (FLNR) in Dubna. The strength of stability of these nuclei is not certain so far. The spontaneous fission and α-decay half-lives T_{SF} and T_α respectively of most of even-even nuclei with Z = 104 - 110 are predicted to be thousands of years. The superheavy nuclei are believed to be α-emitter, but in some isotopes the decay through spontaneous fission is more dominating as compared to α-emission. The half-life of α-decay is an indicator of a possible area of enhanced stability. It is comparatively more around the shell closure nuclei. The α-decay rate depends strongly on Q_α value of decay of a nucleus, which decreases as one approaches the magic number. A decreasing Q_α-value implies higher α-decay half-life. The half-life of nuclei near the shell closure is expected to be larger than their neighbors. Theoretical calculations [4] of α-decay half-lives and spontaneous fission in superheavy mass region have recently shown that the stability of nuclei increases significantly when approaching a closed shell N = 184, which is believed to be the next neutron magic number after N = 126.

In the present work we make use of relativistic mean field model to study the α-decay energy of superheavy isotopes of yet to be experimentally observed Z = 119 nucleus.

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Formalism

The Relativistic Mean Field formalism is used here to investigate the decay properties of superheavy nuclei. The Lagrangian density as given by,

$$\begin{aligned}\mathcal{L} &= \overline{\psi_i}\{i\gamma^\mu\partial_\mu - M\}\psi_i + \frac{1}{2}\partial^\mu\sigma\partial_\mu\sigma - \frac{1}{2}m_\sigma^2\sigma^2 \\ &- \frac{1}{3}g_2\sigma^3 - \frac{1}{4}g_3\sigma^4 - g_s\overline{\psi_i}\psi_i\sigma - \frac{1}{4}\Omega^{\mu\nu}\Omega_{\mu\nu} \\ &+ \frac{1}{2}m_w^2V^\mu V_\mu + \frac{1}{4}c_3(V_\mu V^\mu)^2 - g_w\overline{\psi}_i\gamma^\mu\psi_i V_\mu \\ &- \frac{1}{4}\vec{B}^{\mu\nu}.\vec{B}_{\mu\nu} + \frac{1}{2}m_\rho^2\vec{R}^\mu.\vec{R}_\mu - g_\rho\overline{\psi}_i\gamma^\mu\vec{\tau}\psi_i.\vec{R}^\mu \\ &- \frac{1}{4}F^{\mu\nu}F_{\mu\nu} - e\overline{\psi}_i\gamma^\mu\frac{(1-\tau_3)}{2}\psi_i A_\mu\end{aligned}$$

where ψ is Dirac spinor for nucleon and M is mass of nucleon. The quantities m_σ, m_ω, and m_ρ are the masses of σ, ω, and ρ. The non-linear self interaction coupling of σ mesons is denoted by g_2 and g_3. In the present calculations, we employ NL3 parameterization for

TABLE I: The Comparison of our calculations with FRDM [4] and Experimental data [5].

			Q_α (MeV)		
Nucleus	Z	N	RMF	FRDM	Expt.
^{298}119	119	179	11.375	13.086	
^{294}Ts	117	177	10.341	11.286	10.81±0.1
^{290}Mc	115	175	9.597	10.036	9.95±0.40
^{286}Nh	113	173	8.656	8.966	9.63±0.1
^{297}119	119	178	11.066	12.896	
^{293}Ts	117	176	10.783	11.396	11.03±0.08
^{289}Mc	115	174	9.707	10.096	10.31±0.09
^{285}Nh	113	172	9.894	9.116	9.74±0.08

meson-baryon coupling.

Results and Discussion

In the present work we calculate the binding energy using RMF model with NL3 parameterization. The values of Q_α are calculated from ground state binding energy using the following relation:

$$Q_\alpha = BE(N,Z) - BE(N-2,Z) - BE(2,2)$$

The α-decay chains for the isotopes of yet to be observed experimentally, Z = 119 are obtained from the ground state binding energy calculated using relativistic mean field model with NL3 parameter set. In the present work we calculate Q_α values for two α-decay chains with odd-neutrons and even-neutrons. The decay chains starting from ^{297}119 and ^{298}119 isotopes are presented in Table I. The calculated data are compared with the macroscopic-microscopic model, Finite Range Droplet Model (FRDM) [4] and the experimentally observed decay chains [5]. The values of Q_α are in fairly good agreement with experiments and FRDM. Since nucleus with Z = 119 is still to be observed experimentally, therefore, FRDM binding energy data is the only available data for various isotopes of this nucleus.

In figure 1. two α-decay chains are plotted for more clearer visualization of variation in Q_α energy for the present calculations and experimental values.

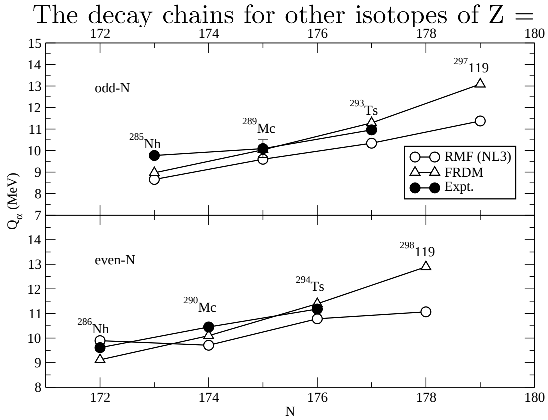

FIG. 1: Comparison of RMF α-decay energy with FRDM and experimental observations [5]. The Q_α values for odd-N isotopes are in upper panel and for even-N nuclei in lower panel.

The decay chains for other isotopes of Z = 119 nucleus are also calculated, but are not included in the present manuscript.

References

[1] W. D. Myers and W. J. Swiatecki, Nucl. Phys. **81**, 1, (1966).

[2] R. K. Gupta, S. K. Patra, and W. Greiner, Mod. Phys. Lett. A **12**, 1727, (1997).; S. Cwiok, P.-H. Heenen, and W. Nazarewicz, Nature **433**, 705, (2005); Bhuyan and S. K. Patra, Mod. Phys. Lett. A **27**, 1250173, (2012).

[3] Yu. Ts. Oganessian, J. Phys. G:Nucl. Part. Phys. **34**, R165, (2007); J. H. Hamilton, S. Hofmann, Y. T. Oganessian, Annu, Rev. Nucl. Part. Sci. **63**, 383, (2013).

[4] P. Möller, J. R. Nix, W. D. Wyers, and W. J. Swiatecki, At. Data Nucl. Data Tables **59**, 185 (1995); P. Möller, J. R. Nix, and K.-L. Kratz, ibid. **66**, 131, (1997).

[5] Yu. Ts. Oganessian, et al., Phys. Rev. Lett. **104**, 142502, (2010).